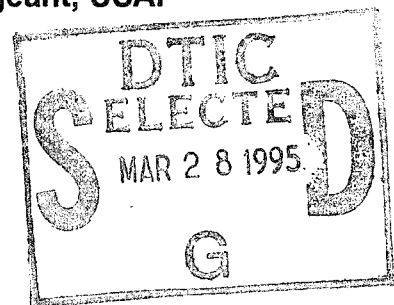


ARMSTRONG
LABORATORY

Controlling Waste Anesthetic Gases

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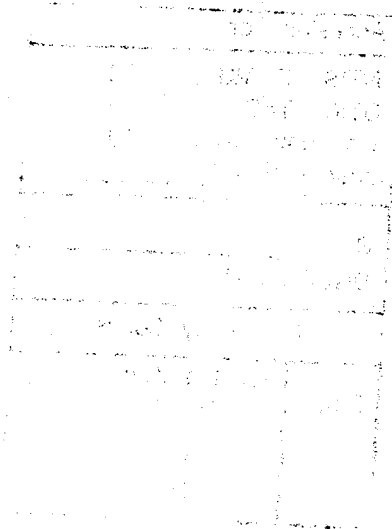
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PURPOSE

This technical report provides Bioenvironmental Engineers (BEEs) with information to effectively manage potential waste anesthetic gas hazards. It supplements Air Force Occupational Safety and Health (AFOSH) Standard 48-8, Controlling Exposures to Hazardous Materials.

BACKGROUND

The Industrial Hygiene Branch at Armstrong Laboratory frequently receives questions regarding the proper monitoring of waste anesthetic gases. The information in previous Air Force literature (e.g., the HQ USAF/SGPA, 14 Nov 1980 policy letter "Control of Occupational Exposures to Anesthetic Gases") is no longer current. Based on the questions we've received and the new literature available, recommendations for monitoring waste anesthetic gases and evaluating sample results are presented in this technical report.

Health Effects

The effect of waste anesthetic gases upon the health of chronically exposed personnel is still uncertain. However, recent scientific and epidemiological studies have given us a cause for concern and require the control of inhalation of anesthetic gases in Air Force medical, dental, and veterinary facilities.

Workers acutely exposed to excessive amounts of anesthetic gases have symptoms of the anesthetized patient. The symptoms are due to the effects on the central nervous system and include drowsiness, irritability, depression, headache, nausea, fatigue, and impairment of judgement and coordination. Studies have also linked chronic exposure to waste anesthetic gases to liver and kidney damage as reported in Occupational and Environmental Reproductive Hazards: A Guide for Clinicians, Williams and Wilkins, 1993.

The effects of exposure to pregnant workers causes the most concern. A study by Guirguis et. al., reported in the British Journal of Industrial Medicine, has shown a weak association between exposure to anesthetic and adverse reproductive outcomes (spontaneous abortions and having children with congenital abnormalities) in exposed women. While the correlation was weak, it is important to consider this information in establishing a program to minimize exposure, especially in this group of workers. A NIOSH alert (NIOSH Publication 94-100) has also linked occupational exposure to nitrous oxide to reduced fertility in female workers.

Regulatory Background

Occupational Exposure Limit (OEL): According to AFOSH Standard 48-8, 21 April 1994, Controlling Exposures to Hazardous Materials, an OEL is the most stringent limit established by either OSHA or ACGIH. The current limit for nitrous oxide is 50 parts per million (ppm) time weighted average (TWA) as established in the 1994-1995 ACGIH TLV Booklet (1994). According to the 1991 Documentation of the Threshold Limit Values and Biological Exposure Indices, this value has been established because "control to this level should prevent embryofetal toxicity in humans and significant decrements in human psychomotor and cognitive functions or other adverse health effects in exposed personnel". Other anesthetic gases (halogenated agents) and their current OEL are listed below:

Halothane (2-bromo-2-chloro-1,1,1 trifluorethane), 50 ppm (ACGIH)
Isoflurane (1-chloro-2,2,2 trifluoroethyldifluoromethyl ether), None
Enflurane (2-chloro-1,1,2 trifluoroethyldifluoromethyl ether), 75 ppm (ACGIH)

Methoxyflurane (2,2-dichloro-1,1-difluoroethyl methyl ether), No OEL; however, the NIOSH Recommended Exposure Limit (REL) is a 15 min TWA ceiling of 2 ppm

AFOSH standard 48-8 also provides monitoring procedures. This report will supplement and clarify those procedures.

Ventilation:

a. Air changes per hour requirements: The following are ventilation rates recommended by American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) for operating rooms. In rooms with recirculating air systems, the minimum dilution ventilation should be 25 air changes per hour (AC/hr), of which only 5 AC/hr must be fresh air. For non-recirculating air systems, 15 AC/hr are recommended. According to the Textbook of Small Animal Surgery, the above requirements are the same for veterinary surgical suites.

b. Pressure Differences: To maintain sterile conditions, the air in the surgical room should be under slight positive pressure. Under such conditions, when the door to the surgical room is opened, air will flow out. This applies to both operating and veterinary surgical rooms.

c. Dental Treatment Rooms (DTRs): ASHRAE recommends ventilation systems in medical treatment rooms have a minimum supply of 6 AC/hr, of which at least 2 AC/hr are outdoor air. The rooms are not required to be under positive pressure. Military Handbook 1191 (1991), Appendix A, further divides treatment rooms according to procedure. For Endodontic DTRs, the rates are the same as the ASHRAE recommendations. However, for Oral Surgery DTRs, the requirement is increased to a minimum supply of 12 AC/hr, of which at least 3 AC/hr are outdoor air. A new edition of Military Handbook 1191 is now in draft. As currently written, it will require that all treatment rooms meet the minimum supply of 12 AC/hr, with at least 3 AC/hr outdoor air.

d. Scavenging Systems (Local Exhaust): Section 8.7.4 of Military Handbook 1191 (1991) states that when anesthetic gases are used, the facility must provide a separate disposal system for removal of waste anesthetic gases. NIOSH Publication 94-100 indicates an exhaust flow rate of 45 liters per minute should be maintained to adequately control exposures to nitrous oxide.

Monitoring

The monitoring methods in this report center around the measurement of nitrous oxide. Nitrous oxide measurement is recommended as an indicator of the effectiveness of waste anesthetic gas controls. Nitrous oxide is used as the surrogate parameter because it is generally in higher concentration than halogenated agents and is readily measured. According to Tran, et. al. (American Industrial Hygiene Association Journal, 1994); when nitrous oxide levels are low, other vapors and gas levels were found to be low as well. The Air Force presently has a contract with the Landauer Company to use their nitrous oxide passive dosimeter for monitoring waste anesthetic gases.

AFOSH Std 48-8 requires the BEE to sample air in the breathing zones for the "worst case" or "representative" workers. Recent studies, indicate this is the most accurate method to perform breathing zone air samples. A study by Rajhans, et. al. (1989), indicated monitoring air at the exhaust grill would correlate to personal exposures. However, a study by Tran, et. al. (1994), indicated 75% of the overexposure would not have been identified by monitoring the exhaust grills with passive dosimeters. The latter report recommended personal breathing zone sampling as the preferred method of evaluating nitrous oxide exposure.

CONTROLLING WASTE ANESTHETIC GASES

Several factors are essential in controlling exposures to waste anesthetic gases. These include: an adequate scavenging system; proper technique used to administer the anesthetic; and control of leaks from exhalation valves, masks and high pressure fittings.

Scavenging system (local exhaust): a system designed to contain and dispose of waste gases and vapors. Scavenging systems can significantly reduce the amount of waste anesthetic gases released into the room.

Anesthesiologist Technique: Inadequate technique can significantly increase airborne levels of anesthetic gases. Small amounts of anesthetic gases can cause a spike in personnel exposure. Proper technique includes:

a. A properly fitted mask. Poor mask technique results in high levels of contamination. Often a very small change in the mask angle is the difference between a good and bad fit. Administering anesthetic carefully coupled with proper scavenging equipment can usually maintain intraoperative levels to less than 50 ppm nitrous oxide and 2 ppm halogenated agents.

b. Following procedures that reduce the chance of releasing anesthetic gas into the room. A release of anesthetic gas can rapidly lead to high concentrations within the room. The following procedures should substantially limit anesthetic gas release:

1. Avoid turning on the nitrous oxide or the vaporizer until the mask is fitted to the patient's face, or the patient is intubated and connected to the circuit. By doing this, the excess gas enters the scavenging system and room contamination is avoided.

2. Where possible, discontinue anesthetic gas flows and empty the reservoir bag prior to suctioning or intubation to prevent the unopposed spill of gas into the operating area environment.

3. At the end of the case, before extubation or removal of the mask, administer oxygen as long as possible so the scavenger system can eliminate the residual and exhaled anesthetic gases. This benefits the patient and keeps airborne levels to a minimum.

4. Carefully fill the vaporizer to avoid spilling volatile anesthetic agents. Small amounts of volatile agents spilled can result in markedly elevated levels in the room.

c. Instructing and periodically reminding patients to breathe through the nose and minimize talking during dental procedures.

Leak Checking-Low Pressure System: The low pressure system is the part of the anesthesia system which extends from the flowmeter to the patient. Leakage from the gas anesthesia machine and absorber is fairly common and develops between scheduled maintenance performed by the manufacturer or service technicians. Leakage from the absorber (Fig. 2) is particularly common and often results from improper reassembly after the soda-lime is changed. The following general test procedures measure leakage from the anesthesia system between the flow meters and the patient. These must be conducted only by users (anesthesiologist and nurse anesthetists) familiar with the equipment or by qualified service personnel (biomedical equipment repair technician). These procedures are general enough for most anesthesia machines, but you should refer to the manufacturer's instructions for your specific model.

a. The carbon dioxide absorber (Fig. 2) is sealed by means of breathing tubes (Fig 2); one length joins openings to the breathing valves and the other joins outlets for the breathing bag (Fig 2) and popoff valve (Fig 3). The breathing bag must be removed.

b. The popoff valve is opened and the vaporizer control switch is turned on.

c. The leak rate from the complete system is measured first. Using any low range flowmeter (except vaporizer oxygen), adjust the flow to maintain a steady pressure of 30 cm H₂O measured on the breathing circuit pressure gauge (Fig 3). The in-flow reading on the flowmeter being used to maintain the pressure then equals the leak rate. CAUTION: Pressure rapidly increases in a tight machine. When flowmeters are adjusted, the pressure gauge must be observed to avoid damage caused by over-pressurizing.

d. Leakage from the vaporizer system is excluded by turning off the vaporizer switch and again adjusting the flowmeter to maintain 30 cm H₂O and compensate for any change in leakage rate.

e. Leakage from the absorber and breathing tubes is then excluded by occluding gas outlet tubing, and adjusting the flow rate, if necessary. In the event that a measurable flow rate remains, leakage is probably through a seal. NOTE: A separate pressure gauge is used for this step.

f. If the leakage rate measured in step 3 exceeds 100 millimeters per minute, corrective action is necessary. A major difference in leakage rates between step 3 and step 5 would indicate the leak source to be the absorber. The necessary action in this case would be to carefully disassemble and reassemble the absorber to insure that all gaskets are in place and all fittings properly sealed. If the absorber leak cannot be corrected, or if excessive leakage remains in step 4 or step 5, notify appropriate personnel that service is required.

Leak Checking-High Pressure System: This system includes the central nitrous oxide lines and the anesthesia machine from the nitrous oxide tanks to the flowmeter (Fig. 1).

a. High pressure nitrous oxide lines are typically flexible pressure tubing with two "quick connect" fittings. These fittings can be tested by immersing in water or by applying a soap solution. The appearance of bubbles indicates a leak. Once corrected, leaks from these fittings recur slowly.

b. The yoke connecting the nitrous oxide tanks is often the major leak source. Apply a soap solution to the yoke to check for leaks. Tightening the fittings often eliminates the leak. Deformed, doubled or missing washers are other common causes of leakage.

c. The anesthesia machine is tested by closing the valve to the rotameter and then pressurizing the machine by opening a tank of Nitrous oxide. The tank valve is then closed and the pressure is recorded. If the pressure drops by more than 10% in 10 minutes, the machine is leaking.

NOTE: Leaks can also be checked by using a real time monitor such as a MIRAN (Infrared Gas Analyzer).

VENTILATION SURVEY

The general ventilation system should be evaluated to establish its effectiveness.

Surgical Suites:

a. Perform a positive/negative pressure survey of the operating rooms. Using a smoke tube, open the door a crack and observe the direction the smoke flows. The room should be under positive pressure (i.e., air flow should be out of the OR) to maintain sterile conditions. If the system is under negative pressure, have the system rebalanced before you continue with the air monitoring.

b. A ventilation survey will be difficult if air enters through diffusers. In this case, check facility drawings to see if there is a supply duct that will be conducive to a pitot tube survey. Also, determine if the air entering the OR is recirculated. If it is not 100% fresh air, then determine the percentage of recirculated air. If you are not able to measure by pitot traverse, then measure the flow at the exhaust grill.

c. After you have measured the air flow, calculate the air changes per hour (AC/hr). ASHRAE suggests systems with non-recirculating air maintain 15 AC/hr, and those with recirculating air systems have a minimum dilution ventilation of 25 AC/hr of which only 5 AC/hr need be fresh outside air.

Dental Treatment Rooms: As stated earlier, Military Handbook 1191 requires a minimum of 6 AC/hr (of which at least 2 AC/hr must be fresh air) for Edodontic DTRs. For Oral Surgery DTRs, the requirement is for 12 AC/hr of which at least 3 AC/hr must be fresh air. As stated earlier, the draft revision of Military Handbook 1191 requires all treatment rooms to meet the latter conditions. It is important to determine if the amount of fresh air flow into the room (via HVAC) changes during the year. For example, in winter there may be more recirculated air; potentially causing the nitrous oxide levels to build up. Consequently, sampling is recommended throughout the year and the level of recirculation must be documented.

Veterinary Clinic: As stated earlier, the requirements for ventilation in a veterinary surgical suite are the same as the hospital surgical suite.

Scavenging System: NIOSH recommends the exhaust rate be maintained at a minimum of 45 liters per minute.

SURGICAL SUITE AIR SAMPLING

Baseline:

a. **Background sampling:** Background sampling is used to detect leaks in the high pressure side of the nitrous oxide delivery system that may go undetected by other methods. This sampling is done by either placing a dosimeter at an exhaust register in each of the operating rooms and delivery rooms, or within 10 feet of the point where the gas enters the room. The sampling location depends on the air flow in the room. Since the room is under positive pressure, waste anesthetic gas may be evacuated from the room by doors that are close to the point the gas enters. But, if you have a good distribution of air flow and a strong exhaust system, the exhaust grill would be the preferred sampling point. This sample should be taken at least 12 hours after a surgery has been performed and ensure no surgery will be performed during the period of sampling (24 to 48 hours). The results should be less than 5 ppm nitrous oxide. Concentrations greater than 5 ppm indicate a high pressure leak in the room.

b. **Personnel Monitoring:** Take breathing zone air samples on representative or worst case workers during different surgical procedures. Results should indicate nitrous oxide concentrations less than 25 ppm, 8-hour TWA. Concentrations significantly higher indicate a low pressure leak, a malfunctioning scavenging system and/or poor technique in administering anesthetic. From the results, establish a baseline concentration for each worker position (e.g., anesthesiologist, surgeon, nurse, assistant). The baseline value can then be compared with future sampling results to determine if the exposure for the specific surgical suite or treatment room is higher than normal.

Semi-Annual: The goal of this survey is to detect changes in nitrous oxide concentration as compared to the baseline. To reduce variables, compare surgical procedures sampled during the semi-annual survey with the same or similar procedures sampled during baseline sampling.

The following information should be collected as potential sampling variables:

- types and number of operations performed during sampling
- approximate age of the anesthetic vaporizers
- type of rebreathing circuit
- method of scavenging (low pressure exhaust or high pressure vacuum)
- mask or intubation
- age of patient
- gas flow rate
- type of anesthetic administering unit

DENTAL TREATMENT ROOMS (DTR)

In dental operations, leakage around the nose mask used to administer anesthetic can cause very high, short term, excursions in nitrous oxide concentrations.

Record the following conditions during each procedure:

- gas flow rate
- type of anesthetic administering unit
- type of scavenging system
- type of mask
- whether rubber dam was used
- ventilation, use of fans
- age of patient
- the extent of patient talking during the procedure
- how well patient maintained nose (vs. mouth) breathing

When checking DTRs for nitrous oxide use, sample representative DTRs from a homogeneous group (i.e., where room volume and ventilation rates are within 10%). DTRs that are not part of a homogeneous group must be sampled individually.

Use five dosimeters for five separate procedures (they do not have to be on the same day). The patients can be pediatric, adult, or a mixture of both. If there is a mixture of pediatric and adult patients, air sample the larger group with 3 dosimeters and the smaller with two.

Select dental procedures that are typical and will last at least 30 minutes from time of gas turn on to the time the patient leaves the DTR. Uncap the dosimeter just before the nitrous oxide is turned on. After the patient leaves the DTR, wait at least 1 air change before recapping the dosimeter. If the procedure is less than 30 minutes, keep the dosimeter uncapped for a minimum of 30 minutes. Keep notes that indicate the time when the gas is turned on and off, when the patient leaves the room, etc.

The dentist should provide the BEE with the total time (duration) per day nitrous oxide is normally administered. The time period for each procedure starts when nitrous oxide is turned on and ends 1 air change after the patient departs the room. This takes into account patient "off-gassing" and airborne residuals.

Nitrous oxide concentrations in DTRs are typically highly variable due to the difficulty in maintaining a good nosepiece seal and controlling waste gas escape through the patients mouth. Consequently, the intent of the DTR air sampling survey is to determine compliance with the excursion limit, which is 3 times the OEL (150 ppm) as well as the 8 hr TWA (50 ppm). Under no circumstance is the exposure to exceed 5 times the OEL.

LANDAUER PASSIVE DOSIMETERS

NOTE: Use the dosimeter promptly after receipt. The dosimeter must be sent back to Landauer within 120 days of the "Begin Wear Date". Unused dosimeters must also be sent back to the manufacturer.

Sampling Time

a. The dosimeters are intended primarily for personal breathing zone air samples. When possible, they should be worn for a full shift. However, during sampling in dental treatment rooms, recommend at least 30 minutes sampling time.

b. If the dosimeters are to be used for other purposes such as area monitoring, Landauer recommends a minimum sampling time of two hours and a maximum sampling time of forty hours. If the sampling time is less than two hours, the dosimeter may be recapped after the exposure is over and uncapped during another identical or similar surgical procedure. This should allow you to get a total of two or more hours of sampling.

c. If a two hour sample cannot be provided, Landauer can perform an analysis of samples with as little as 9 ppm-hours mass concentration. The lowest detectable mass (loading rate) concentration is a value established by Landauer, which has a nonlinear response to various sampling times. The sensitivity of the dosimeters decreases when a shorter sampling time is used.

Limit of Detection

Limit of Detection for the Landauer Nitrous Oxide Dosimeter

Exposure Time (hrs)	Lowest Detectable Mass Concentration (PPM-hours)	Calculated TWA For Exposure (PPM-TWA)
0.5	9	18
1.0	9	9
1.5	9	6
2.0	10	5
2.5	10	4
3.0	10	3
3.5	10	3
4.0	10	3
4.5	10	2
5.0	11	2

To calculate the minimum concentration which can be detected for a sample, look at the sampling time and the corresponding lowest detectable mass. Then divide the lowest detectable mass by the exposure time.

EXAMPLE: A surgical procedure is sampled that lasts only 30 minutes (0.5 hours). Looking at the chart the lowest detectable mass is 9 ppm-hours. So the lowest detectable mass of 9 is divided by 0.5 hours. This gives you a detection limit of 18 ppm-TWA, averaged over the sampling period.

Returning the Dosimeters

Landauer dosimeters should be sent directly to the manufacturer and not to Armstrong Laboratory.

Landauer Analytical Laboratory
R.S. Landauer J. and Co.
Division of Tech/Ops, Inc
2 Science Road
Glenwood, IL 60425-1586
(312) 755-7000

Results Interpretation

Landauer reports three pieces of information for each dosimeter: the hours uncapped (sampling time); ppm-hours (the mass of nitrous oxide collected on the dosimeter); and TWA (the average concentration during the time sampled; i.e., [ppm-hours]/[the hours uncapped]).

AL Landauer Contract

Armstrong Laboratory has a contract with R.S. Landauer J. and Co. to provide Air Force bases nitrous oxide dosimeters. The contract is for a period of one year. Each base is asked to review annually their requirement for dosimeters. On 1 February the Industrial Hygiene Branch (AL/OEMI) requests MAJCOMs provide the dosimeter requirement for their bases for the coming fiscal year. This information should be submitted to AL/OEMI by the MAJCOMs by 31 March. Dosimeters will then be sent out to those bases requiring dosimeters either in October and April or in January and July of the following fiscal year.

When a base requires more dosimeters than is stated in the contract, they must be purchased directly from Landauer. Armstrong Laboratory does not receive any extra dosimeters.

Other Survey Techniques

Miran: The Miran 1B Portable Ambient Air Analyzer may be used to measure the levels of nitrous oxide. The Miran is a single-beam infrared spectrometer. You can either use the internal calibration or use the closed loop calibration system. The closed loop system will offer you the most accurate readings. The Miran can measure level of nitrous oxide from 0 to 2000 ppm at a wavelength of 4.68 μm .

Consultative Help: If you have any questions regarding the monitoring of waste anesthetic gases, or the use of Landauer dosimeters, contact the Armstrong Laboratory Occupational Medicine Division Industrial Hygiene Branch at DSN 240-6137. Personnel can answer questions as well as provide field support for specialized surveys.

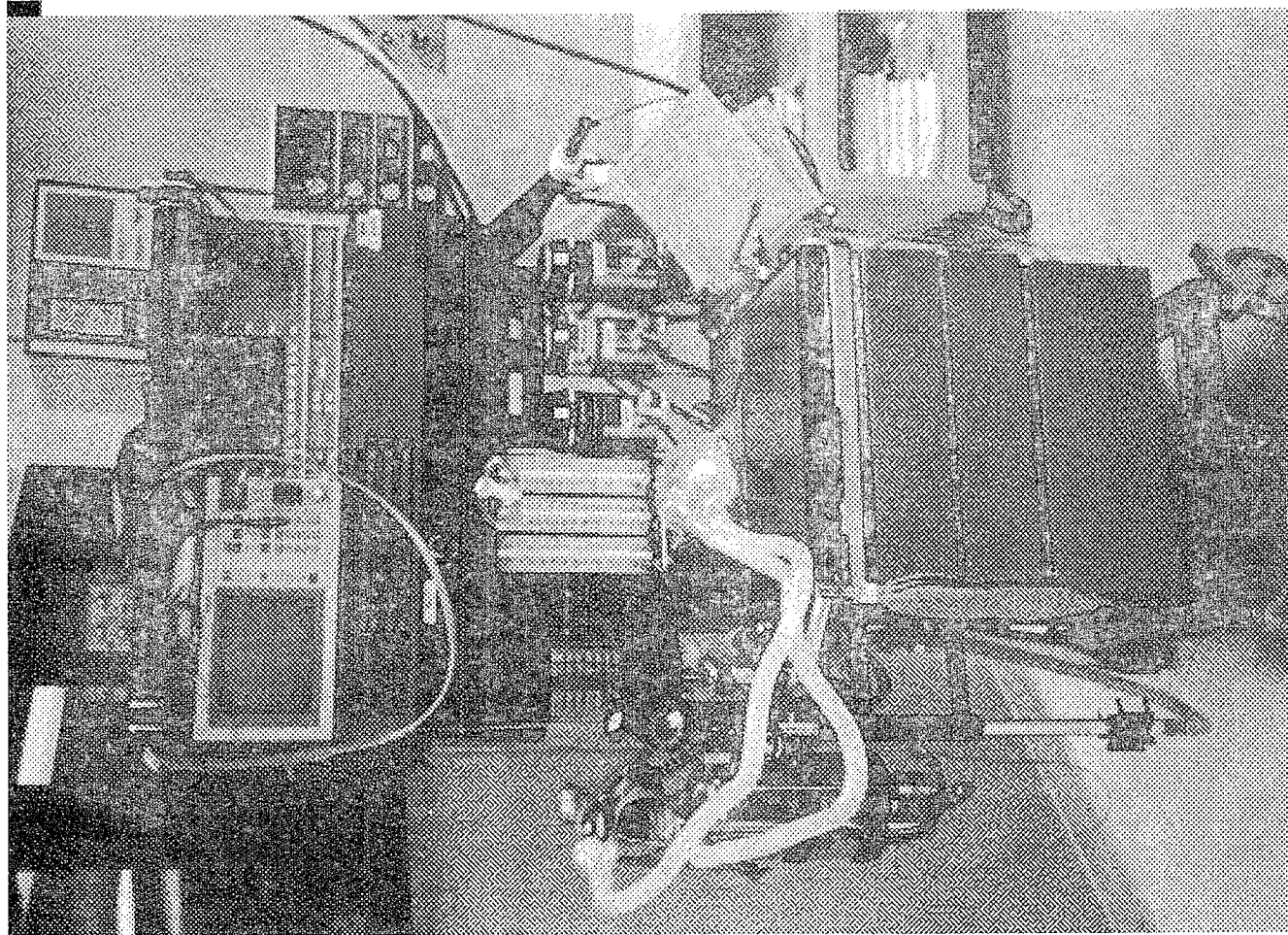
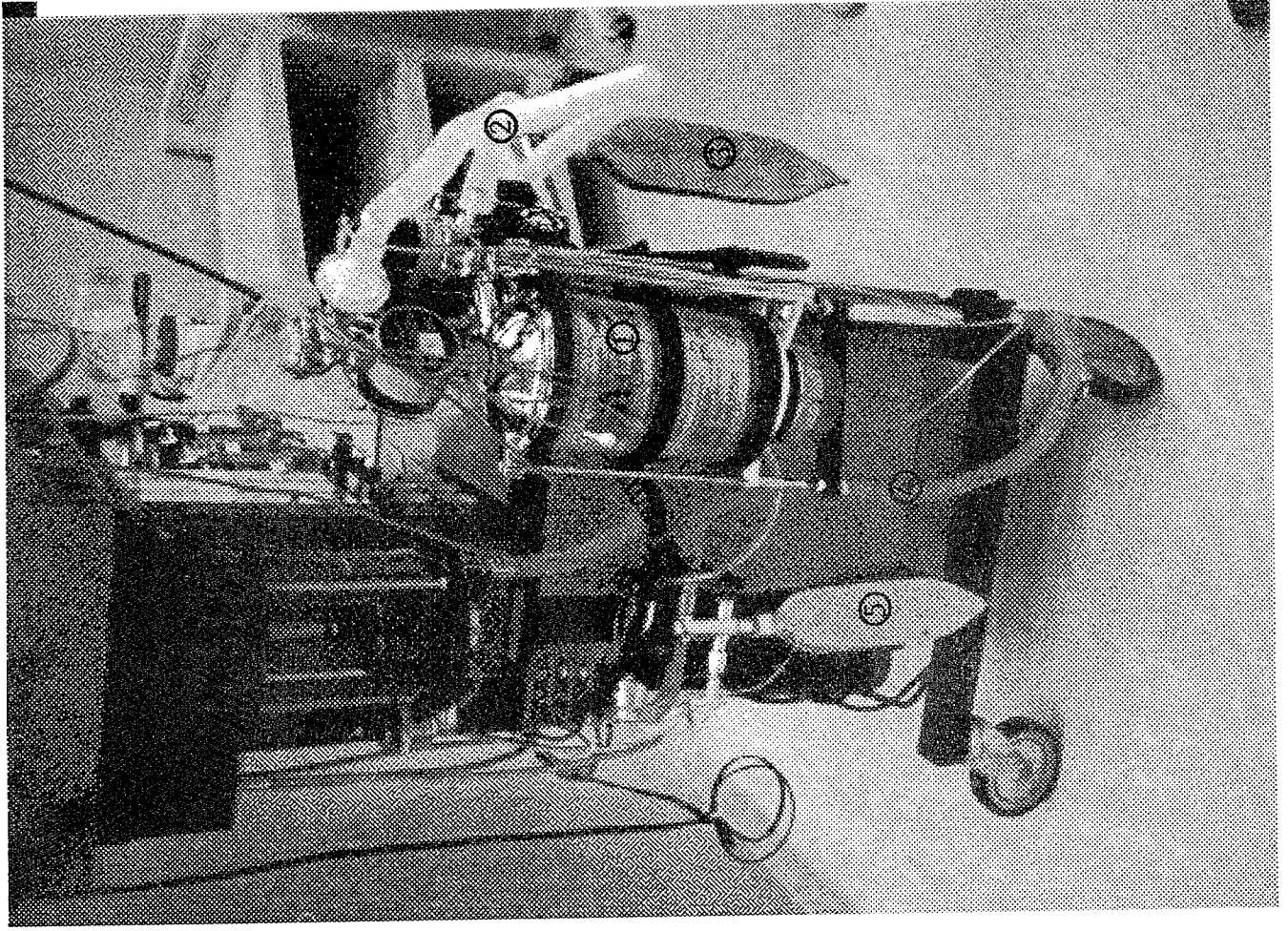


Figure 1, Front view of Narkomed 2B Anesthesia Cart, manufactured by North American Drager. From this view you can see the patient delivery sytem on the left hand side. The white tubing on the top of the delivery system would go to the patient. Also on the right hand side under the monitor shelf, you can see small canisters containing Halothane, Enflurane and Isoflurane. This machine receives its nitrous oxide from high pressure lines that feed into the operating room.

Figure 2, Left side view of Narkomed 2B Anesthesia Cart . This view shows where most of the leakage occurs. On the right hand side of this picture you see the delivery system which includes the absorber (soda-lime canister).

1. Absorber
2. Breathing Tube
3. Breathing Bag
4. Tubing to Scavenging System
5. Scavenging System Bag



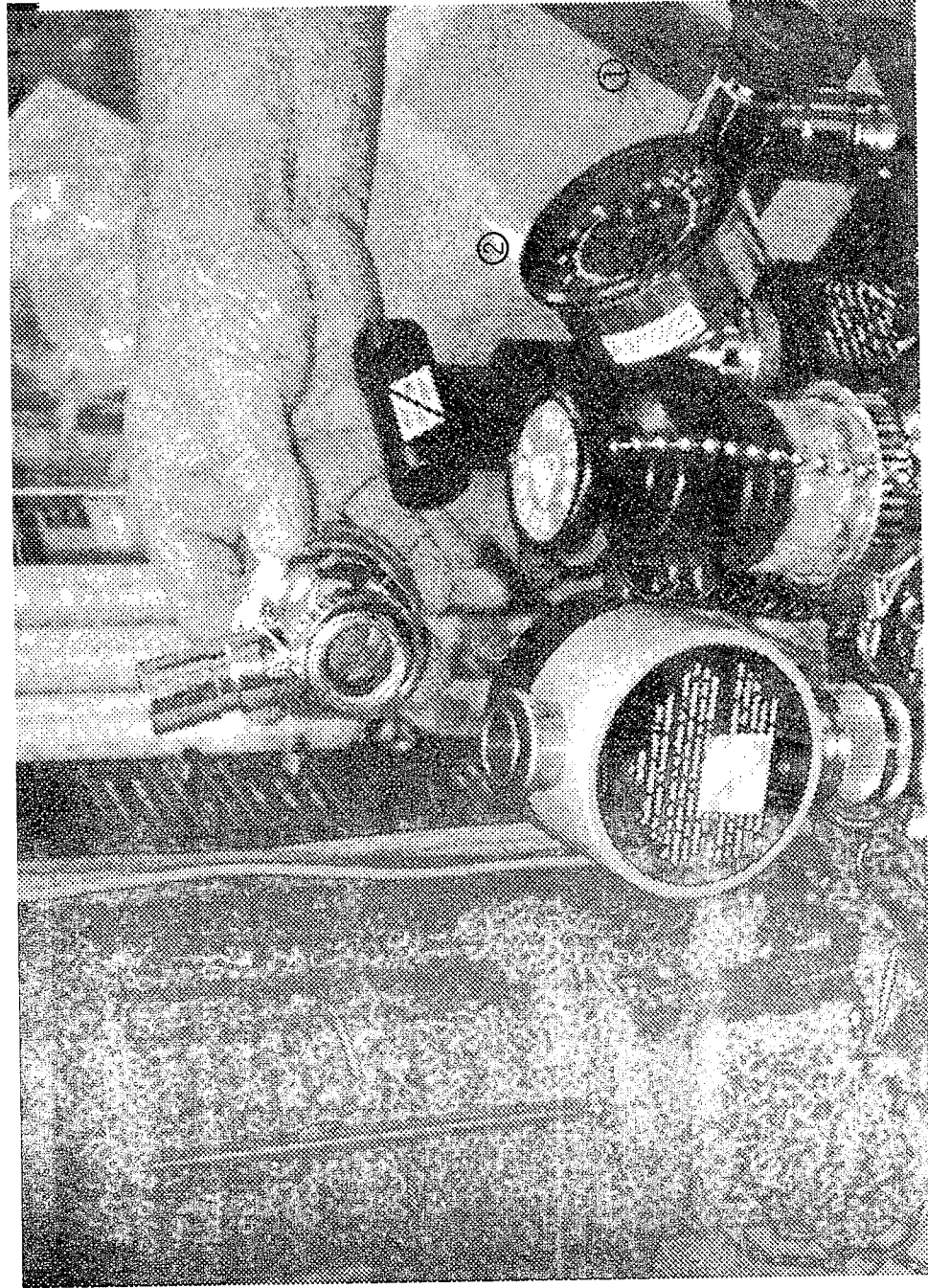
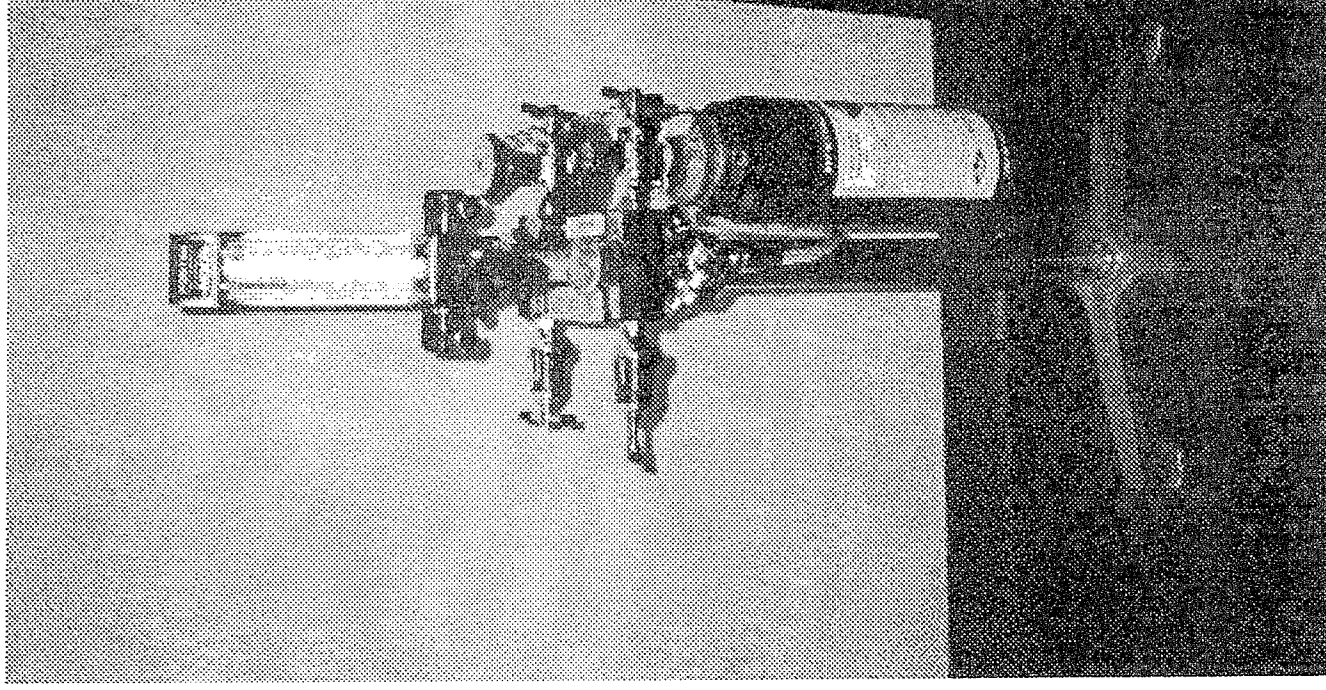


Figure 3, Top of delivery system. In this picture it shows a connection that may cause leakage due to deterioration of the rubber o-ring. In the bottom right hand corner is the pop-off valve(1). Also on the right hand side you can see the pressure gauge (2) which is used to indicate leaks when the cart operates as a closed system. The connections on the top of the delivery system are one of the major causes of leakage of nitrous oxide.

Figure 4, Dental Anesthesia Cart. The cart consist of the nitrous oxide and oxygen cylinders, and the delivery system.



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